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US 720418
US4187527A
Us 4075677A
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(54) High voltage adjustment system

(57) A system for adjustment of high voltage from a supply to maintain a substantially constant gradient across a gap between an electrostatically charged source of atomised coating material particles and a target to be coated by the particles, includes a circuit for sensing current flow between the source and target and for feeding a signal related to the sensed current to a high voltage-adjust circuit in the supply. A current flow signal is received at a terminal 618 and fed through a filter circuit 620. The amplified signal is coupled at a terminal 485 to the circuit which establishes the high voltage for the system.

The bulk of the supply and control circuitry is identical to that shown in specifications 1591111 and 1591112.

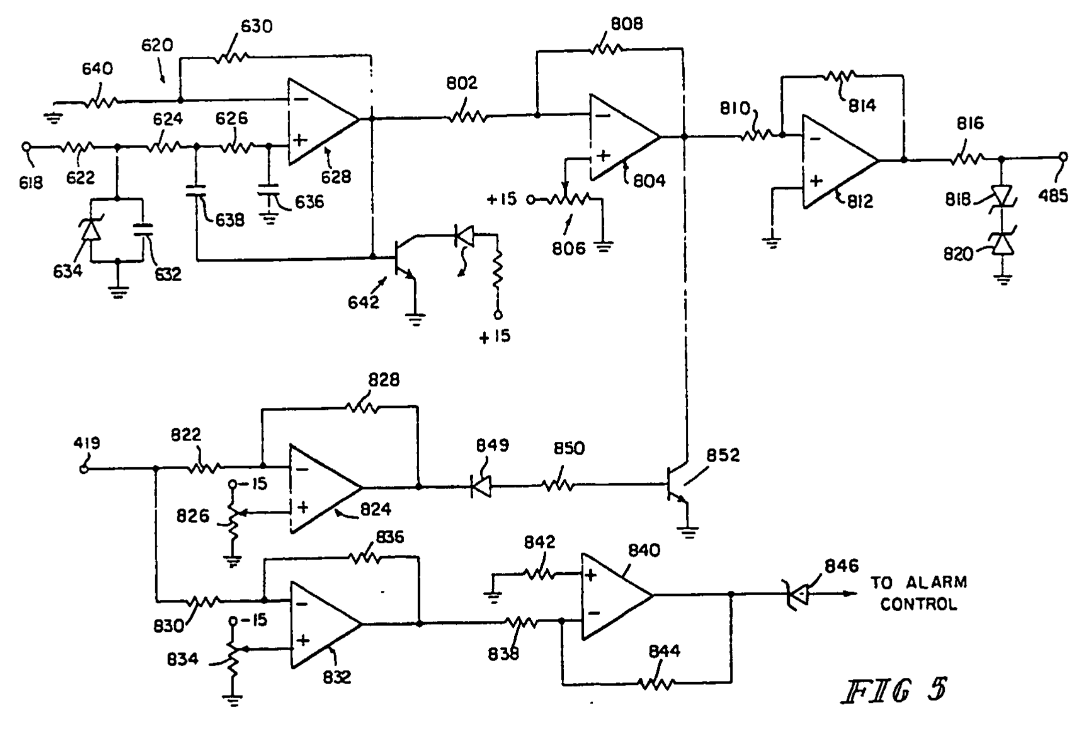

FIG 5

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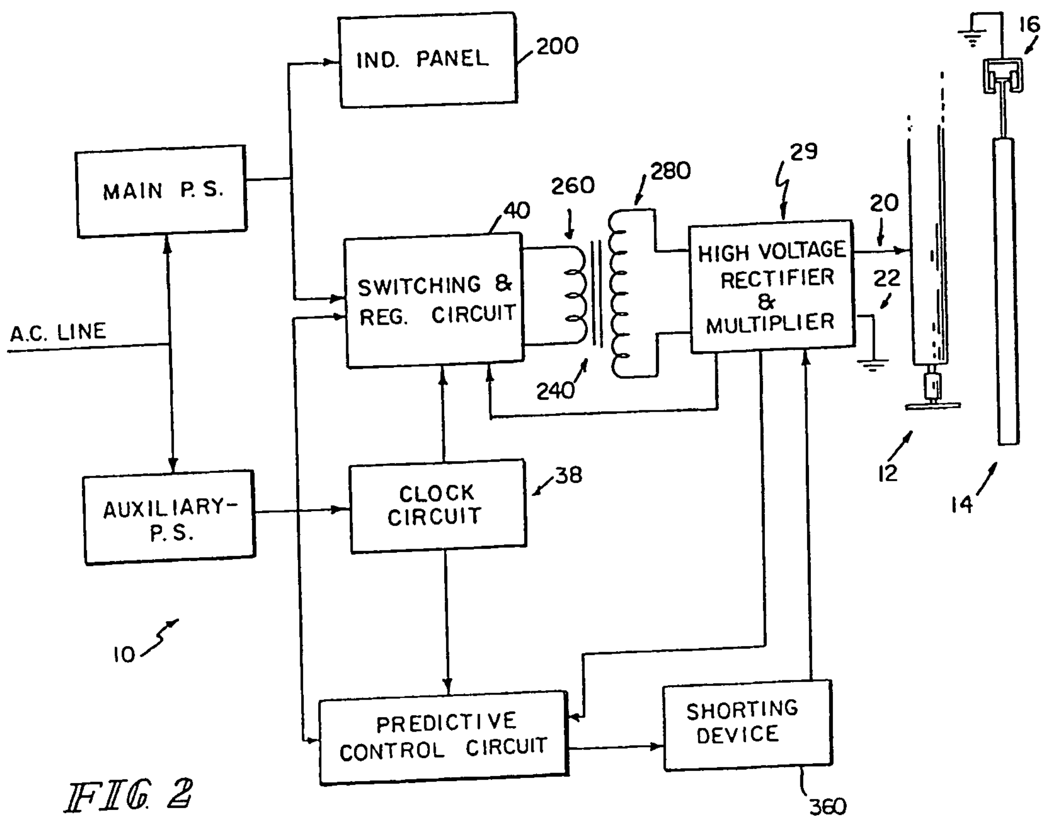
IND. PANEL
200
MAIN P.S.
SWITCHING &
REG. CIRCUIT
40
260
280
240
29
HIGH VOLTAGE
RECTIFIER
&
MULTIPLIER
20
22
16
12
14
A.C. LINE
AUXILIARY-
P.S.
CLOCK
CIRCUIT
38
10
PREDICTIVE
CONTROL CIRCUIT
SHORTING
DEVICE
360

FIG. 2

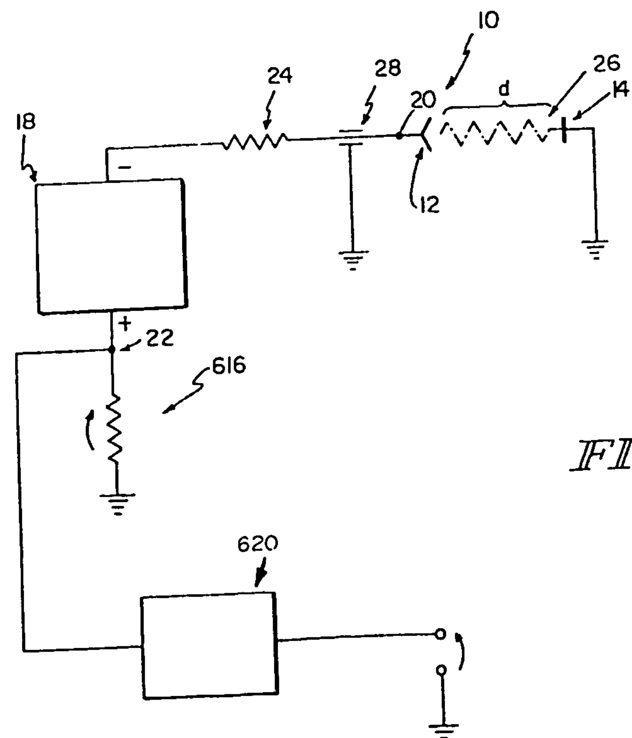
10
24
28
26
d
14
20
18
12
22
616
620

FIG. 1

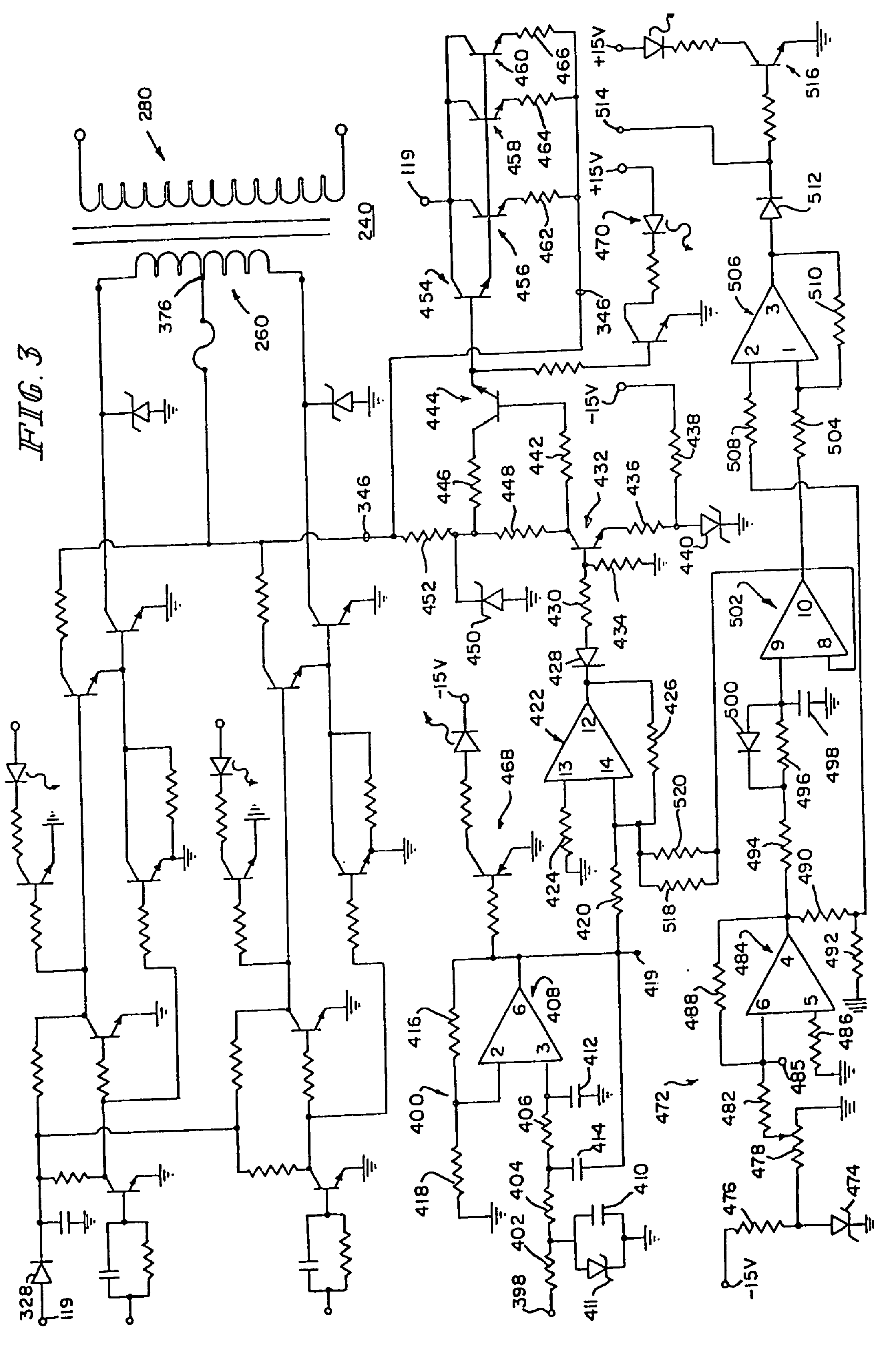

FIG. 3

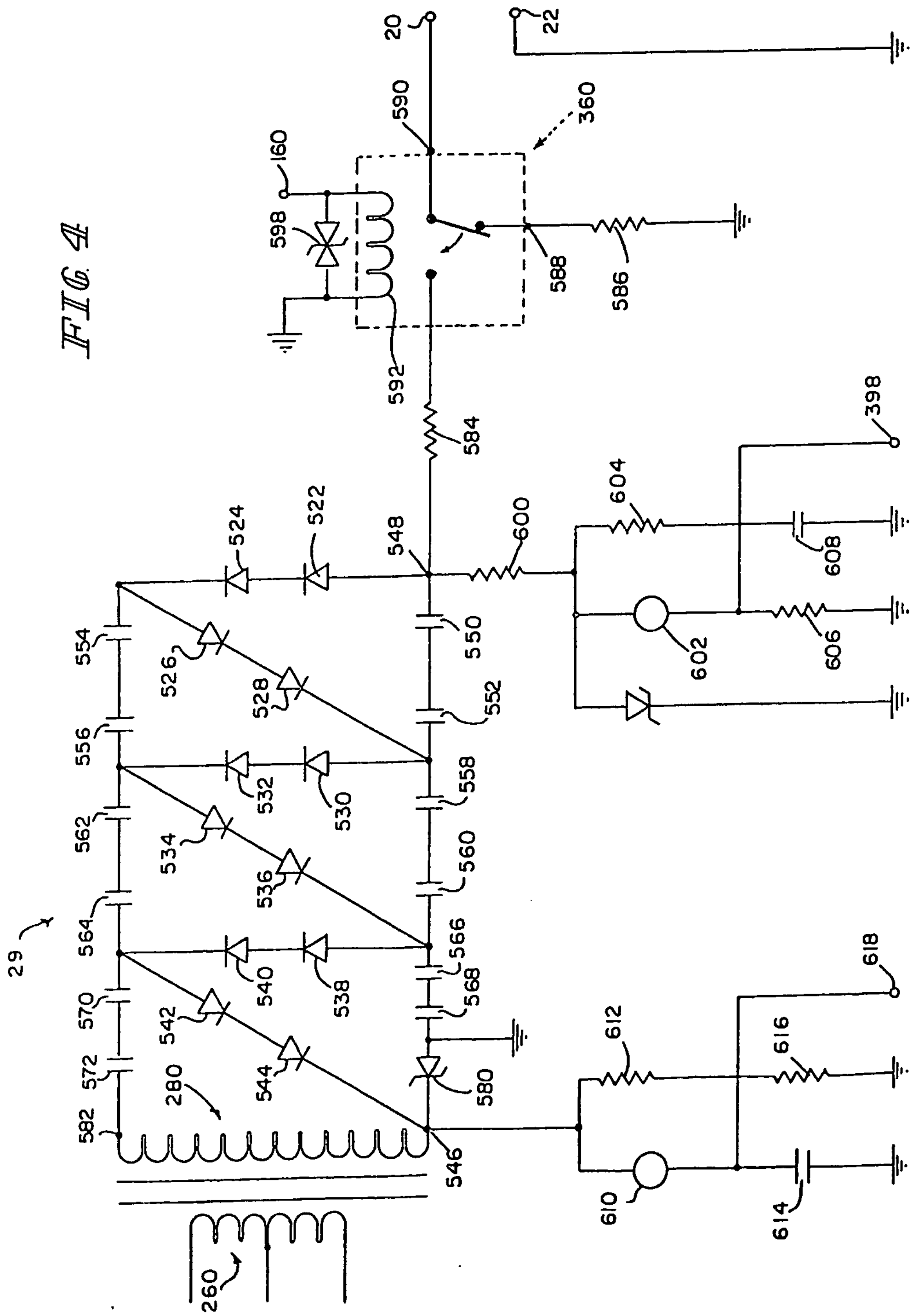
20
22
590
360
160
598
588
586
592
584
398
604
522
524
548
600
608
554
526
528
550
602
606
552
556
558
532
530
562
534
536
560
29
564
566
540
538
568
570
542
618
612
616
572
280
544
580
582
546
610
614
260

FIG. 4

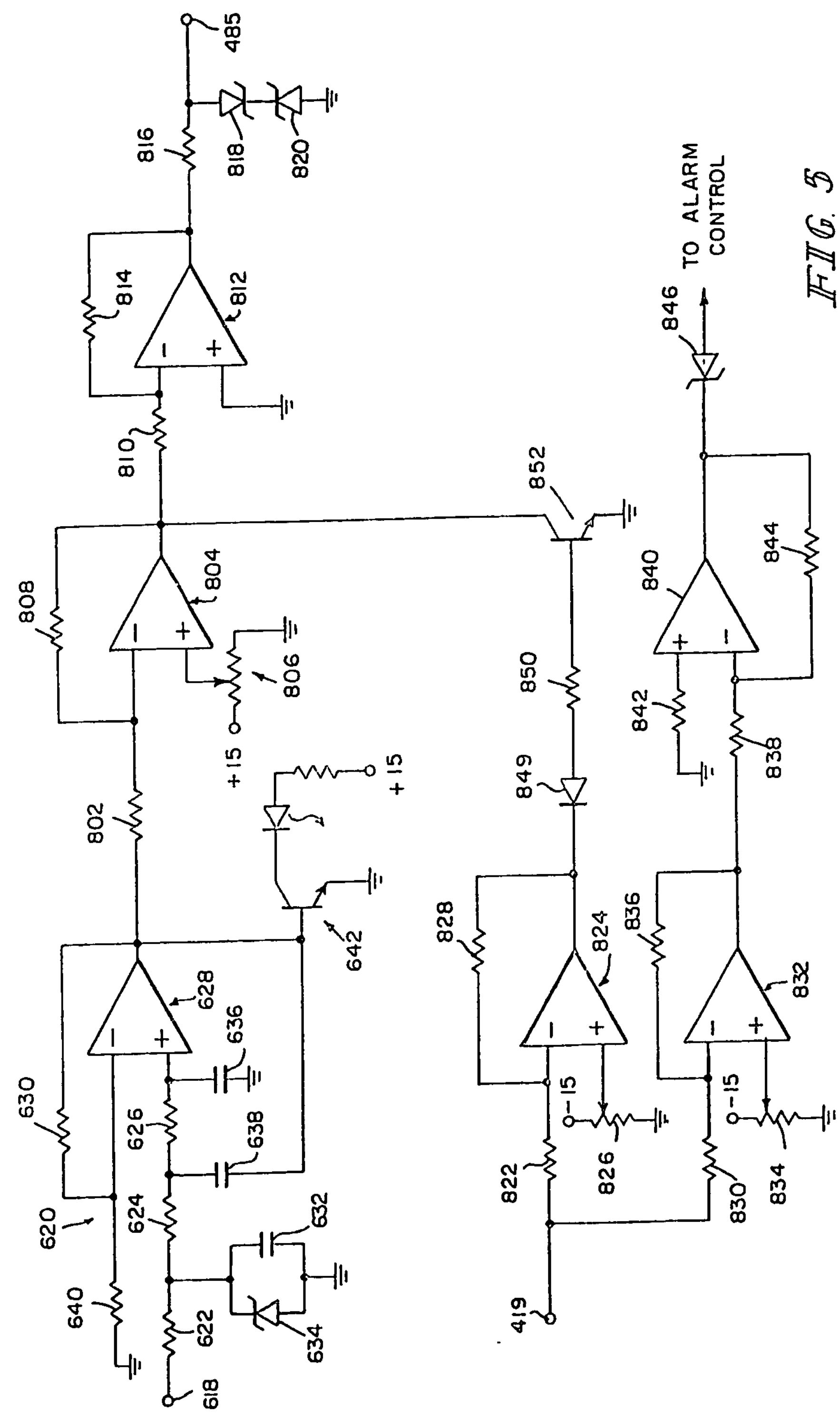
485
816
818
820
814
812
810
852
808
804
806
+15
846
TO ALARM CONTROL
840
844
850
842
838
849
+15
802
828
824
836
642
628
636
832
630
626
638
−15
826
834
620
624
632
822
830
640
622
634
419
618

FIG. 5

SPECIFICATION

High voltage adjustment system

This invention relates to a high voltage adjustment system, for example, for an electrostatic coating material dispensing system or apparatus for adjusting the electrostatic potential difference between a coating-dispensing device and a target to be coated by the coating dispensed by such device. Typically, the space between the device and target is referred to as the "head-target" spacing. The existence of a potential difference between the head and target results in the establishment of an electrostatic field between the head and target. Electrostatically charged particles of coating material migrate from the head under the influence of the filed to the target to coat it.

Usually, articles to be coated will be conveyed past the dispensing device on a conveyor. In many situations, such articles are subject to motion, not only past the dispensing device, but also oscillatory motion, e.g. swinging motion towards and away from the high voltage electrode of the dispensing device.

In industrial electrostatic coating systems, a high voltage DC power supply is used which produces, across a pair of terminals, a high potential of for example, 140 kilovolts (KV) DC. Typically, one terminal is at ground or approximately ground potential while the other terminal is held at a high (frequently negative) potential. This high potential terminal is connected to a charging device which charges particles of the coating material. The charging device also frequently serves to atomise particles of coating material from, for example, a fluid mass. The atomised and charged coating material particles move through the electric field between the charging device and the articles in the direction of the article, strike the article, and stick to it. The article is maintained at a low potential, e.g. approximately ground, just as is the low potential terminal of the high voltage supply.

In an automatic electrostatic coating installation, articles to be coated are usually carried by a conveyor and are thus free to swing back and forth in the direction of the charging device. As an article moves towards the charging device, the potential gradient between the charging device and the article can increase quite rapidly. The rapidity of the increase depends in part upon how rapidly the article is swinging. The maximum and minimum values of the potential gradient depend upon the amplitude of the swing. The current between the charging device and the article, which results in large part from the flow of charged particles of coating material across the space therebetween varies as the potential gradient between the article and the charging device varies, with the current increasing as the spacing between the article and charging device decreases toward a minimum and decreasing as the spacing between the article and the charging device increases to a maximum. Appreciation of these characteristics has been demonstrated by United States Patents Nos. 3,851,618, 3,875,892, 3,894,272, 4,075,677 and 4,187,527.

As can be appreciated, a considerable hazard presented by movement of articles to be coated with respect to the charging device, is the possibility of spark discharge across the space between the charging device and the freely moving articles. The need for a system which can prevent or reduce such spark discharge is apparent. Operators of electrostatic coating apparatus occasionally occupy work stations quite close to the charging device, the articles being coated, or to both. Additionally, some materials used in the coating process, or in operations related to the coating process, are volatile, and the vapours of such a material may be present in the atmosphere near the apparatus. Many such materials are flammable. Further, fine particles of coating material are frequently suspended in the atmosphere surrounding the apparatus.

The safety hazards presented by the possibility of a high voltage spark between the charging device and the article to be coated evinces the need for a system which can predict with reasonable accuracy conditions conductive to arcing and which can act to prevent it. Additionally, high voltage arcing can be detrimental to parts of the electrostatic coating apparatus itself, e.g. the high voltage supply.

As the aforementioned patents discuss, it is useful to be able to predict conditions which favour, for example, high voltage arcing. It is also useful to predict other potentially hazardous conditions, such as the passage on the conveyor of an ungrounded article to be coated, or target, and to react to such conditions. It will be appreciated that application of charged coating material particles to an ungrounded target should be avoided, since it will result in storage on the ungrounded target of an electric charge. Occasionally, such electric charge can reach relatively large magnitude and become a hazard in itself to workers in the vicinity. For example, a worker touching or passing close by such a target can receive an unpleasant electrical shock. Further, as the ungrounded and charged target itself passes close by grounded conveyor parts and the like, sparking can occur which can ignite volatile, flammable vapour commonly found where such coating operations take place.

According to this invention, a high voltage adjustment system includes a pair of output terminals, at least one of the terminals being movable relatively toward and away from the other, means for establishing a voltage across

the output terminals, the voltage establishing means including a control electrode for receiving a control signal for adjusting the voltage across the output terminals to a desired value, means for sensing current flow between the output terminals and for producing a signal indicative of such current flow, a summing point, means for coupling the current signal sensing means to the summing point, and means for coupling the summing point to the control electrode to sum the current signal and the control signal, the voltage establishing means reacting to increasing magnitude current flow between the output terminals by reducing the voltage across the output terminals, and to decreasing magnitude current flow between the output terminals by increasing the voltage across the output terminals.

The current between the output terminals may be subject to rather high frequency transient perburbations in response to slight variations in the spacing between the output terminals, and other phenomena. These transient perturbations, if supplied to the control electrode, can cause the potential across the output terminals to oscillate as the voltage source "hunts" in an effort to establish exactly a proper potential difference between the output terminals. To alleviate this problem, a "dead zone" may be established in the control system by providing, in the means for coupling the current signal sensing means to the control electrode, means for filtering a signal related to current flow between the output terminals, and for producing the signal indicative of current flow. The filter means may include an input terminal, means for coupling the filter means input terminal to the sensing means, an output terminal, and means for coupling the filter means output terminal to the control electrode. The filter means filters substantially all transient perturbation-related components above a selected frequency from the signal related to current flow between the output terminals. The signal indicative of current flow includes, as a result, substantially only components of the signal related to current flow below the selected frequency.

The invention will now be described by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a combined block and schematic diagram illustrating the principle of the present invention;

Figure 2 is a combined block and schematic diagram illustrating a system for utilizing the present invention;

Figure 3 is a somewhat more detailed schematic diagram of a portion of the system Fig. 2;

Figure 4 is a somewhat more detailed schematic diagram of a portion of the system of Fig. 2; and

Figure 5 is a somewhat detailed schematic and block diagram of a portion of the system of Fig.2.

Referring now to Figs. 1–2, the coating material dispensing system 10 of the present invention includes a dispensing device, or head, 12 for dispensing a coating material upon an article which is typically moving past the head 12 on a conveyor 16. A source 18 of electrostatic potential includes a terminal 20 coupled to head 12 and a terminal 22 coupled through ground to the conveyor 16. Ordinarily, the connection by which the target 14 is attached to the conveyor 16 insures that target 14 also will be maintained at ground potential, or approximately ground potential. As can best be appreciated by referring to Fig. 1, the potential source 18 behaves as though it were supplying potential through a source resistance 24 to head 12, and from head 12 through a load resistance 26 (in broken lines) attributable mainly to target 14 and the spacing d between head 12 and target 14 and conveyor 16, to ground. Some source capacitance 28 will also affect the behavior of the electrostatic potential source 18.

The established potential difference between the output terminals 20, 22 results in the establishment of a potential gradient between the head 12 and the target 14. If the potential available across terminals 20, 22 were constant, the gradient would vary, as illustrated by the broken line representation of load resistance 26 on Fig. 1, depending among other things upon the head 12-target 14 spacing d. It must be borne in mind that target 14 is typically free to swing toward and away from head 12 (i.e., generally transversely of its direction of motion along the conveyor 16). The control system of the present invention is designed to accommodate such changes in the spacing d, and to maintain the gradient between head 12 and target 14 substantially constant notwithstanding such spacing variations between the head 12 and the target 14. It will be immediately appreciated that, in order to do this, the control system must react to a reduction in the head 12-target 14 spacing by reducing the potential difference between terminals 20, 22, and to increased head 12-target 14 spacing by increasing the potential difference between terminals 20, 22.

The illustrated control system by which the head 12-target 14 spacing is determined recognizes that the rate of transfer of coating material from head 12 to target 14 is directly related to the current flow between the head 12 and target 14, since each individual particle of coating material which migrates along the field between the head 12 and target 14 carries a charge. Thus, monitoring of the current flow between head 12 and target 14 gives a fairly accurate indication, within limits, of the head 12-target 14 spacing. Other factors do, of course, also affect current flow

between head 12 and target 14. However, these other factors typically are related to variations in current flow which are small in comparison to the current flow attributable to coating material flow during normal coating operations.

Turning now to the function of control system and with reference again to Fig.1, the system includes means, illustratively a resistor, 616 for sensing variations in the head 12-target 14 current flow. These variations are initially interpreted, as discussed above, as changes in the coating material transfer rate from head 12 to target 14.

With reference to Fig. 3, the control system further includes a circuit 472 for selecting and establishing a desired potential difference between the head 12 and target 14 for a given desired coating material transfer rate, hereinafter called the normal transfer rate. It will be appreciated that circuit 472 is actually provided to establish a given normal potential difference between terminals 20 and 22. However, this normal potential difference between terminals 20, 22, coupled with the normal spacing between the head 12 and target 14 establishes a normal coating material transfer rate. Therefore, for future reference, the circuit 472 is hereinafter referred to as a high voltage adjust circuit. In the illustrative embodiment, the high voltage adjust circuit 472 is part of a high voltage regulator 40 illustrated in Fig.2 in block form, and in Fig. 3 in schematic form.

With reference to Fig.3, a terminal 398 of the regulator circuit continuously monitors the high potential established between terminals 20, 22 of the potential soure 18, and more specifically, of the high voltage rectifier and multiplier 29 of source 18. The specific construction of high voltage rectifier and multiplier 29 will be described in connection with Fig.4. For purposes of the discussion of Fig.3, it will suffice to understand that the signal on terminal 398 is directly proportional to the output high voltage between terminals 20, 22 of Fig. 1. Therefore, the signal on terminal 398 contains a substantial DC component corresponding to the quite high DC component of the voltage across terminals 20, 22, e.g., 140 KV DC. However, the voltage across terminals 20, 22, and thus the signal on terminal 398, also includes a considerable amount of AC "ripple" or "noise" from several sources. For example, much of the noise can be traced to 5 KHz switching in the high voltage source 18 by the action of clock circuit 38 and high voltage regulator 40. In order to obtain a substantially noise-free signal related to the direct-current voltage only across terminals 20, 22, it is necessary to filter substantially all AC components from the signal on terminal 398.

Since much of this AC noise occurs at the 5 KHz switching rate, or multiples thereof, a filter which rolls off at a frequency considerably lower than 5 KHz is used in the disclosed embodiment. The disclosed filter 400 is a three-pole, active filter of the type commonly knowwn as a Butterworth filter. Filter 400 rolls off at 100Hz. terminal 398, the input terminal of filter 400, is coupled through three series resistors 402, 404, 406 to the non-inverting input terminal, pin 3, of an integrated circuit operational amplifier 408. Hereinafter such devices shall be referred to simply as "amplifiers", with the understanding that integrated circuits are widely used for such devices.

The junction of resistors 402, 404 is coupled through a parallel combination of a capcitor 410 and a zener diode 411 to ground. Pin 3 of amplifier 408 is coupled to ground through a capacitor 412. The output terminal, pin 6, of amplifier 408 is returned to the junction of resistors 404, 406 through a capacitor 414. Pin 6 is also coupled through a feeedback resistor 416 to the inverting input terminal, pin 2, of amplifier 408. Pin 2 is copuled to ground through a resistor 418.

The output signal on pin 6 of amplifier 408 is coupled through a resistor 420 to the inverting input terminal, pin 14, of an amplifier 422. The noninverting terminal, pin 13, of amplifier 422 is coupled through a resistor 424 to ground. Feedback resistor 426 is coupled between the output terminal, pin 12, of amplifier 422 and pin 14 thereof.

Pin 12 of amplifier 422 is also coupled to the cathode of a diode 428, the anode of which is coupled through a series resistor 430 to the base of a driver transistor 432. The base of transistor 432 is coupled through a resistor 434 to ground. The emitter of transistor 432 is coupled through a pair of series resistors 436, 438 to a −15 volt supply. The junction of resistors 436, 438 is coupled to the anode of a Zener diode 440, the cathode of which is grounded.

The collector of transistor 432 is coupled through a resistor 442 to the base of a regulating predriver transistor 444. The collector of transistor 444 is coupled through two resistors 446, 448 to the collector of transistor 432. The cathode of a Zener diode 450 is coupled to the junction of resistors 446, 448. The amount of the Zener diode 450 is grounded. The cathode of zener diode 450 is coupled through a resistor 452 to the regulating voltage supply bus 346.

The emitter of regulator predriver transistor 444 is coupled to the base of a regulator driver transistor 454. The collector of transistor 454 is coupled to a direct current voltage supply terminal 119 which carries, for example, 28 volts DC. The emitter of transistor 454 is coupled to the bases of three parallel coupled regulator output transistors 456, 458, 460. The collectors of transistors 456–460 are coupled to voltage supply terminal 119.

Their emitters are coupled through series resistors 462, 464, 466, respectively, to supply bus 346.

The DC component of the high voltage related signal on terminal 398 is supplied to pin 14 of amplifier 422. Amplifier 422 and transistors 432, 444, and 454 amplify this high voltage DC-related signal and control transistors 456–460 therewith the magnitude of the direct-current voltage on supply bus 346. This voltage, which is fed to the center tap terminal 376 cf high voltage transformer primary winding 260, is the voltage which is switched across primary winding 260 and stepped up in secondary winding 280. The voltage generated across secondary winding 280 is thereby linearly controlled by the regulator. Indicator circuits 468, 470, which include transistor-controlled LEDs provide visual indications of signal flow through Butterworth filter 400 and regulator predriver transistor 444, respectively.

The high voltage adjust circuit 472 also operates through the high voltage regulator. Circuit 472 includes a Zener diode 474, the cathode of which is grounded and the anode of which is coupled through a series resistor 476 to −15 volts. A high voltage adjustment potentiometer 478 is coupled across Zener diode 474. The wiper of potentiometer 478 is coupled through a series resistor 482 to the inverting input terminal 485 of an amplifier 484. The noninverting input terminal, pin 5, of amplifier 484 is coupled through a resistor 486 to ground. The output terminal, pin 4, of amplifier 484 is coupled thorugh a feedback resistor 488 to pin 6 thereof. Pin 4 of amplifier 484 is also coupled through two series resistors 490, 492 to ground.

The output terminal, pin 4, of amplifier 484 is further coupled through two series time constant-determining resistors 494, 496 to one terminal of a soft-start capacitor 498, the remaining terminal of which is grounded. A diode 500 is coupled in parallel relationship to resistor 496 to provide a discharging time constant for capacitor 498 which differs from the charging time constant thereof.

The junction of diode 500 and capacitor 498 is coupled to a noninverting input terminal, pin 9 of an amplifier 502. The inverting input terminal, pin 8, and the output terminal, pin 10, of amplifier 502 are shorted together, making amplifier 502 a noninverting amplifier. Pin 10 of amplifier 502 is also coupled through a series resistor 504 to the inverting input terminal, pin 1, of an amplifier 506. The non-inverting input terminal, pin 2, of amplifier 506 is coupled through a series resistor 508 to the junction of resistors 490, 492. A feedback resistor 510 is coupled between the output terminal, pin 3, of amplifier 506 and pin thereof. Pin 3 of amplifier 506 is further coupled to the anode of a diode 512, the cathode of which forms a terminal 514. An indicator circuit 516 including a transistor-controlled LED similar to the indicator circuits previously described, provides a visual indication of signal at terminal 514. Pin 10 of amplifier 502 is also coupled to the inverting input terminal, pin 14, of amplifier 422 through parallel resistors 518, 520.

It will be appreciated that high voltage adjust potential from potentiometer 478 will be supplied through amplifiers 484, 502 to the inverting input terminal, pin 14, of amplifier 422. The signal at terminal 398, which is directly related to the potential difference between terminals 20, 22 is also supplied to pin 14. It shoiuld be understood that these signals linearly control regulator output transistors 456–460 in a manner similar to that in which actual high voltage related signals at terminal 398 of Butterworth filter 400 control transistors 456–460.

Referring now to Fig. 4, high voltage rectifier and multiplier 29 will be discussed. In the illustrated embodiment, the high voltage is a high-magnitude negative voltage, e.g., minus 140 KV DC. to generate this high voltage, the voltage variations induced in high voltage transformer 240 secondary winding 280 are rectified and multiplied, illustratively by a factor of six, in circuit 29. Twelve high voltage rectifying diodes 522–544 are coupled in series between terminal 546 of secondary winding 280 and the negative high voltage terminal 548. Six pairs of series coupled storage capacitors 550, 552; 554, 556; 558, 560; 562, 564; 568; and 570, 572 are coupled, respectively, between the anode of diode 522 and the anode of diode 530; the cathode of diode 524 and the cathode of diode 532; the anode of diode 530 and the anode of diode 538; the cathode of diode 532 and the cathode of diode 540; the anode of diode 538 and the anode of a Zener diode 580, the cathode of which is coupled to terminal 546; and the cathode of diode 540 and other terminal 582 of secondary winding 280.

A large-value series resistor 584 is coupled between negative high voltage terminal 548 and output terminal 20. A series combination of a resistor 586 and terminals 588, 590 of a shorting device 360 are coupled between terminal 20 and ground. Terminals 588, 590 are the normally closed terminals of a solenoid-actuated relay. The control solenoid 592 of this relay is serially coupled between a terminal 160 of the control panel 200 (Fig. 2) and ground. A bidirectional zener diode 598 is also coupled between terminal 160 and ground to protect against excessive voltage across solenoid 592. When winding 592 is actuated, high voltage is supplied from terminal 548 through resistor 584 and device 360 to terminal 20. Any interruption of current flow through winding 592 returns device 360 to its position illustrated in Fig. 4, shorting

output terminal 20 through resistor 586 to ground.

High voltage circuit 29 additionally includes the current and high voltage sensing circuits. One terminal of a very large-value resistor 600 is coupled to terminal 548. The remaining terminal of resistor 600 is coupled to the parallel combination of a kilovolt meter 602 and a meter-scale controlling resistor 604. The other terminal of this parallel combination is terminal 398 of active filter 400 of Fig. 3. The parallel combination of a large-value resistor 606 and a capacitor 608 is coupled between terminal 398 and ground. In the circuit including resistors 600, 606, the resistance value of the parallel combination of KV meter 602 and scale resistor 604 is negligible compared to the values of resistors 600 and 606. Thus, resistors 600, 606 constitute an extremely high resistance voltage divider between negative high potential terminal 548 and ground. As was previously mentioned, a voltage signal directly related to the high voltage at terminal 548 is available at terminal 398.

One terminal of a parallel combination of a microammeter 610 and a scale resistor 612 is coupled to terminal 546 of secondary winding 280. A parallel combination of a capacitor 614 and the current-sensing resistor 616 is coupled between the other terminal 618 of the microammeter-scale resistor circuit and ground. Since the junction of high voltage capacitor 568 and Zener diode 580 is at ground, it can be seen that terminal 618 will be maintained at a slightly positive potential (less than or equal to the reverse breakdown voltage of Zener diode 580). Since the microammeter 618 is coupled between terminal 546 of secondary winding 280 and ground, the current through the circuit will be equal to the current flowing between terminals 20, 22 of high voltage circuit 29. The voltage at terminal 618 will always be directly proportional to the current flowing between terminals 20, 22.

Referring now to Fig. 5, the signal representative of current flow between high voltage circuit 29 20, 22 is coupled from terminal 618 to a three-pole active filter 620. Filter 620 is Butterworth filter and is similar to filter 400 of Fig. 3.

Active filter 620 includes three series resistors 622, 624, 626 coupled between terminal 618 and the non-inverting input terminal, pin 3, of an amplifier 628. The output terminal, pin 6, of amplifier 628 is coupled through a feedback resistor 630 to the inverting input terminal, pin 2, thereof. Coupled between the junction of resistors 622, 624 and ground are a capacitor 632 and a Zener diode 634, the anode of which is grounded. A capacitor 636 is coupled between pin 3 and ground. A capacitor 638 is coupled between pin 6 and the junction of resistors 624, 626. Pin 2 is coupled to ground through a resistor 640. An indicator circuit 642 including a transistor-controlled LED provides a visual indication of the presence of signal at the output terminal of amplifier 628 of filter 620.

The output terminal, pin 6, of amplifier 628 of the pack-return current filter is coupled through a resistor 802 to the inverting input terminal (–) of an amplifier 804. Feedback is provided from the output terminal of amplifier 804 to the inverting input terminal thereof through a resistor 808. A reference voltage is established on the non-inverting input terminal (+) of amplifier 804 through a potentiomter 806 which is coupled between a +15 volt source and ground. The output terminal of amplifier 804 is also coupled through a resistor 810 to the inverting (–) input terminal of an amplifier 812. Feedback is provided from the output terminal of amplifier 812 through a resistor 814 to the inverting input terminal thereof. the non-inverting input terminal (+) of amplifier 812 is grounded. The output terminal of amplifier 812 is coupled through the series combination of a resistor 816, a Zener diode 818, and a Zener diode 820 to ground. The junction of resistor 816 and the anode of Zener diode 818 is coupled directly to terminal 485 (see Fig. 3).

A terminal 419 formed at the output (pin 6) of amplifier 408 (see Fig. 3) is coupled through a resistor 822 to the inverting input terminal (–) of an amplifier 824. Feedback is provided through a resistor 828 from the output terminal of amplifier 824 to the inverting input terminal thereof. A negative potential is established on the non-inverting input terminal (+) of amplifier 824 by a potentiometer 826 which is coupled between a –15 volt power supply and ground.

A resistor 830 is coupled between terminal 419 and the inverting input terminal (–) of an amplifier 832. The output terminal of amplifier 832 is coupled through a feedback resistor 836 to its inverting input terminal. A negative voltage is established on the non-inverting input terminal (+) of amplifier 832 by a potentiometer 834 which is coupled between a –15 volt power supply and ground. The output terminal of amplifier 832 is also coupled through a series resistor 838 to the inverting input terminal (–) of an amplifier 840. The output terminal of amplifier 840 is coupled through a feedback resistor 844 to its inverting input terminal. The non-inverting input terminal (+) of amplifier 840 is coupled through a resistor 842 to ground.

The output terminal of amplifier 824 is coupled to the series combination of a Zener diode 849 and a resistor 850 to the base of a transistor 852. The collector of transistor 852 is coupled to the output terminal of amplifier 804. The emitter of transistor 852 is coupled to ground. The output terminal of amplifier

840 is coupled through a zener diode 846 to an alarm control point.

In operation, the circuit of fig. 5 continuously monitors the filtered output across the high voltage terminals 20, 22 at terminal 419. The circuit of Fig. 5 also continuously monitors the current flowing between terminals 20, 22 (Fig 4) as fittered by the current filter 620. Amplifier 824 and its associated circuitry establish the maximum magnitude of the potential available across terminals 20, 22. This maximum potential is adjustable by adjustment of potentiometer 826. The minimum desirable potential between terminals 20, 22, below which it is necessary or desirable to inhibit a coating operation is determined by the setting of potentiometer 834 in circuit with amplifier 832. This minimum threshold potential information is inverted in the circuit including amplifier 840 and provided directly to an alarm control point of a known type of circuit for interrupting the high potential supplied to terminals 20,22 (Fig.4). Amplifiers 824, 832 and their associated circuitry thus establish an operational window within which the high voltage adjustment circuit is permitted to operate. When the high voltage approaches the upper set point established by potentiometer 826, the output of amplifier 824 switches from essentially the negative supply voltage to amplifier 824 to essentially the positive supply voltage to amplifier 824. This in turn saturates transistor 852. The output of amplifier 812 remains positive and the positive potential at terminal 485 causes the high voltage output across terminals 20, 22 (Fig.4) to decrease.

When the potential across terminals 20, 22 decreases below the lower set point established by potentiometer 834, the output of amplifier 832 switches from essentially the positive potential supplied to amplifier 832 to essentially the negative potential supplied to amplifier 832. This signal is inverted in amplifier 840, and drives the alarm circuitry and overload circuitry, the configuration of which can be found in the above-referenced United States patents.

The effect of the Fig. 5 circuit is to subtract from the high voltage adjust signal a signal related to current flow between head 12 and target 14. The potential difference across the head 12-target 14 spacing can be set up initially with a voltmeter with no coating material flowing from head 12 to target 14 (essentially a zero-current condition or infinite load resistance 26—Fig.1). This potential is established at any desired value, for example, 140 KV. This will result in, for example, a potential difference between head 12 and target 14 when target 14 is in its normal position (not swinging transversely of the direction of motion of the target 14 along the conveyor 16) and at a desired normal coating material dispensing rate, of 135 KV. It will be appreciated, however, that if, for any reason, the signal indicative of current flow at the output terminal, pin 6, of amplifier 628 increases, indicating an increased coating material flow rate, the potential difference between terminals 20, 22 will automatically be reduced through the normal action of the regulator circuit illustrated in Fig.3. Conversely, any reduction in the magnitude of the signal indicative of current flow at the output terminal, pin 6, of amplifier 628 results automatically, through the action of the regulator circuit of Fig. 3, in an increase in the potential difference between terminals 20, 22. The effect of this is to maintain the gradient between the output terminals 20, 22 of the potential source 18 substantially constant notwithstanding variations in the head 12-target 14 spacing or any other parameter which tends to cause a variation in coating material transfer rate or current flow between terminals 20, 22.

CLAIMS

1. A high voltage adjustment system including a pair of output terminals, at least one of the terminals being movable relatively toward and away from the other, means for establishing a voltage across the output terminals, the voltage establishing means including a control electrode for receiving a control signal adjusting the voltage across the output terminals to a desired value, means for sensing current flow between the output terminals and for producing a signal indicative of such current flow, a summing point, means for coupling the current signal sensing means to the summing point, and means for coupling the summing point to the control electrode to sum the current signal and the control signal, the voltage establishing means reacting to increasing magnitude current flow between the output terminals by reducing the voltage across the output terminals, and to decreasing magnitude current flow between the output terminals by increasing the voltage across the output terminals.

2. The system of claim 1 wherein the means for coupling the current signal sensing means to the summing point comprises means for filtering a signal related to current flow between the output terminals and for producing the signal indicative of current flow, the filter means including an input terminal and means for coupling the filter means input terminal to the sensing means and an output terminal and means for coupling the filter means output terminal to the summing point, the filter means filtering substantially all of the components above a selected frequency from the signal related to current flow between the output terminals.

3. A coating material dispensing system including a dispensing device, means for generating a potential difference between the

dispensing device and a target to be coated with the coating material, the article being movable relative to the dispensing device such that the device-target spacing is variable, the potential generating means including means for selecting a desired normal potential difference between the device and target for a given desired spacing between the device and target, means for sensing the device-target spacing, and means for increasing the potential difference between the device and target as the spacing between the device and target increases and for decreasing the potential difference between the device and target as the spacing decreases.

4. A coating material dispensing system including a dispensing head, means for generating an electrostatic potential difference between the head and a target to be coated with the coating material, the rate of transfer of coating material from the head to the target, and thus the current flow between the head and target, being variable, the potential generating means including means for selecting a desired potential difference between the head and target for a given desired coating material transfer rate, means for sensing variations in coating material transfer rate, and means responsive to the rate variations sensed by the sensing means to increase the potential difference between the head and target as the rate tends to decrease and for decreasing the potential difference between the head and target as the rate tends to increase.

5. The system of claim 4 wherein the sensing means includes means for filtering substantially all alternating components of the transfer rate above a selected corner frequency and for providing a substantially direct current transfer rate signal.

6. The system of claim 5 wherein the corner frequency is 100 HZ.

7. The system of claim 3 wherein the sensing means for filtering substantially all alternating components of the spacing above a selected corner frequency and for providing a substantially direct current spacing variation signal.

8. A method for controlling the potential difference between a coating material dispensing device and a target to be coated by material dispensed from the device, in which a potential source is coupled between the dispensing device and target to maintain a potential difference therebetween, the method comprising the steps of monitoring the rate of transfer of coating material from the device to the target and adjusting the potential difference between the device and target such that the potential difference tends to increase as the rate tends to decrease, the potential difference tends to decrease as the rate tends to increase, and a substantially constant rate results in a substantially constant potential difference.

9. The method of claim 8 wherein the step of monitoring the rate of transfer of coating material comprises the steps of monitoring current flow between the device and target and developing a component of current flow related to the transfer rate.

10. An apparatus for controlling the potential difference between a coating material dispensing device and a target to be coated by material dispensed from the device, including a potential source, means for coupling the potential source to the dispensing device and target to maintain a potential difference therebetween, means for monitoring the rate of transfer of coating material from the device to the target, and means for coupling the monitoring means to the potential source to provide a transfer rate-related signal thereto.

11. A high voltage adjustment system constructed and arranged substantially as hereinbefore described and shown in the drawings.

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